On high-redshift quasar absorption spectra and the Riemannian geometry of the Universe

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Abstract

We study the observed small deviations of high-redshift quasar absorption spectra that are interpreted as a possible evidence for a variable fine structure constant. On the contrary, we claim that the effect could be completely attributed to the small amount of cosmic shear beyond the standard Friedmann expanding Universe.

Owing to the rapid increase of the high-resolution spectroscopy of QSO absorption systems and the novel many-multiplet method that allows an order of magnitude greater precision compared with the previous alkali-doublet method [1, 2], we are witnessing analyses of high-redshift quasar spectra to the unprecedented level of precision. The most intriguing result of these analyses is the claim of the 4.1σ evidence for a redshift variation of the fine structure constant inferred from small deviations of spectra.

In the literature one can find a lot of speculative ideas with new particles or extra dimensions (see references in [2]) that produce the varying α_e. In this work we adopt a rather conservative wisdom considering α_e constant at any redshift and try to explain small deviations of spectra as a consequence of the Riemannian geometry of the Universe beyond the Friedmann expansion. The $\alpha_e(0)$ at zero momentum transfer is a dimensionless coupling constant directly measurable in scattering and spectroscopic experiments. This fact guided Armand Wyler to calculate α_e starting from the conformal group and symmetry [3] as a symmetry of Maxwell equations:

$$\alpha_e(0) = \frac{9}{8\pi^4}(\frac{\pi^5}{2^4 5!})^{\frac{1}{4}}.$$

His work was strongly criticised [4] showing that one can find other similar expressions for α_e. We can make a comment that one can actually find similar expressions for any real number but it would be necessary to understand a derivation of Wyler's formula with special attention to the conformal symmetry and the dimensionality of the physical spacetime.

For example, the conformal unification scheme for strong and electroweak interactions [5] can explain the appearance and breaking of discrete, gauge and conformal symmetries in a natural way. This approach can strengthen our belief that $\alpha_e(0)$ is constant in any local frame irrespective of the cosmic distance (redshift).

The existence of cold and hot dark matter as spinning particles [6] and the role of conformal symmetry at the largest distances within the Einstein-Cartan gravity reveals the reduction of Newton's gravitational coupling constant to the dimensionless number of order unity [7]:

$$G_N \rho_\infty H_\infty^{-2} = \frac{3}{4\pi}.$$

We choose the redshift distortion as a link between two different interpretations of measurements. Acknowledging the standard relation for the redshift:

$$\frac{\omega_E}{\omega_R} = 1 + z,$$

$$\omega_E(\omega_R) \equiv emitted(received)\ frequency,$$

the interpretation of Refs.[1, 2] could then be described as

$$\frac{\tilde{\omega}_E}{\omega_R(G)} - \frac{\omega_E}{\omega_R(G)} = \tilde{z}(G) - z(G) \equiv \delta z(\alpha_z), \tag{1}$$

$$G \equiv geometry\ defined\ by\ Hubble's\ expansion.$$

Our interpretation relies on the modified Riemannian geometry of the expanding Universe that also contains vorticity, acceleration and shear [8]:

$$\frac{\omega_E}{\omega_R(\tilde{G})} - \frac{\omega_E}{\omega_R(G)} = z(\tilde{G}) - z(G) \equiv \delta z(\tilde{G}), \tag{2}$$

$$\tilde{G} \equiv H + \omega + shear + accel.$$

Assuming small perturbations of the Friedmann metric, following Sachs and Wolfe [9] one obtains

$$ds^2 = R^2(\eta)[\eta_{\mu\nu} + h_{\mu\nu}]dx^\mu dx^\nu,$$

$$dt = R(\eta)d\eta,\ \eta = conformal\ time,$$

$$\delta z(\tilde{G}) = (z+1)\int_0^{\eta_R - \eta_E} [\frac{1}{2}\frac{\partial h_{ij}}{\partial \eta} e^i e^j - \frac{\partial h_{i0}}{\partial \eta} e^i] dy, \tag{3}$$

$$\mu = 0,1,2,3;\ i = 1,2,3; \eta_{\mu\nu} = diag(+1,-1,-1,-1).$$

The metric of Obukhov and Korotky [10] contains everything we need:

$$ds^2 = dt^2 - R^2(t)(dx^2 + ka^2(x)dy^2) - r^2(t)dz^2 - 2R(t)b(x)dydt,$$

$$b(x) = \sqrt{\chi}a(x),\ a(x) = Ae^{mx},\ \chi, A, m, k = const.$$

From Eq.(3) we conclude that only shear contributes to the redshift distortion (it is assumed that the acceleration parameter χ does not depend on time):

$$k = 1,\ a(x) = 1,\ h_{zz} = -\frac{r^2(\eta) - R^2(\eta)}{R^2(\eta)},\ h_{y\eta} = -\sqrt{\chi},$$

$$assume: \ \frac{\dot{r}}{r} - \frac{\dot{R}}{R} = \lambda\frac{\dot{R}}{R}, \ \dot{R} \equiv \frac{dR}{dt}, \lambda = const. << 1, \ r(t) \simeq R(t),$$

$$\delta z(\tilde{G}) = -\frac{\lambda}{3}(z+1)\ln(z+1). \tag{4}$$

Acknowledging the results of Ref.[2], we make an order of magnitude estimate of the shear anisotropy parameter λ:

$$\delta z(\alpha_z) = \delta z(\tilde{G}), \tag{5}$$

$$\delta\omega = q_1 x + q_2 y \simeq (2q_1 + 4q_2)\frac{\delta\alpha_e}{\alpha_e} \simeq -|\mathcal{O}(10^{-2})|cm^{-1},$$

$$\omega \simeq \mathcal{O}(10^4)cm^{-1}, \ \bar{z} = 1.5,$$

$$\Rightarrow \lambda = +|\mathcal{O}(10^{-6})|. \tag{6}$$

It is also observed [2] that the effect of the redshift distortion grows with redshift and this is in accord with our Eq.(4). One can study the evolution of shear within the fluid-flow approach of Hawking [11] adding the shear viscosity term to the energy-momentum tensor [12] as a consequence of the radiation-matter coupling in primordial plasma and as a source of shear anisotropy.

Similarly, studying primordial mass density fluctuations or the angular momentum of galaxies, one can deduce the parameters of vorticity and acceleration [13].

Recent supernova searches and their implications on the value of the cosmological constant give controversial results at the redshift $z > 1$ (data are only marginally consistent with the positive cosmological constant). The role of hot dark matter (light neutrinos) is possibly underestimated in current cosmological fits of data. Small-scale simulations within the standard cold dark matter scenario cannot explain all observed features.

The present complex situation concerning cosmological parameters could be resolved by more precise data (SDSS, MAP mission, etc.) and more sophisticated cosmological models.

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